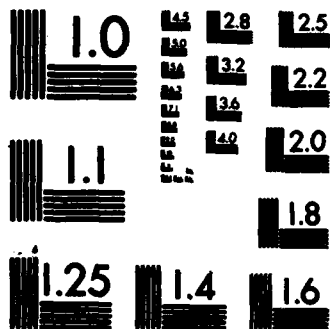MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FINAL TECHNICAL REPORT

ENERGETIC ION BEAM PLASMA INTERACTIONS

by

Russell Kulsrud

Plasma Physics Laboratory
Princeton University

March 9, 1984

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION	1b. RESTRICTIVE MARKINGS
Unclassified	

2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT
	Approved for public release;
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	distribution unlimited

4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
	AFOSR-TR- 84-0228

6a. NAME OF PERFORMING ORGANIZATION	6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
Princeton University		AFOSR/NP

6c. ADDRESS (City, State and ZIP Code)	7b. ADDRESS (City, State and ZIP Code)
Plasma Physics Laboratory Princeton, NJ 08544	Bolling AFB, DC 20332

8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
AFOSR	NP	AFOSR-83-0203

8c. ADDRESS (City, State and ZIP Code)	10. SOURCE OF FUNDING NOS.			
Bolling AFB, DC 20332	PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
	61102F	2301	A7	

11. TITLE (Include Security Classification)
ENERGETIC ION BEAM PLASMA INTERACTIONS

12. PERSONAL AUTHOR(S)
Russell Kulsrud

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Final	FROM 15 Jun 83 TO 15 Jan 84	March 9, 1984	6

16. SUPPLEMENTARY NOTATION

17.	COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This final report covers the work carried out under the Air Force Office of Scientific Research Grant AFOSR-83-0203 made to Princeton University during the period June 15, 1983 to January 15, 1984. This grant formed the conclusion of research first carried out under research grant AFOSR-81-0106. During, this concluding period the group at Princeton completed the investigation of the amount of neutralization of the energetic ion beam and carried out preliminary investigations of possible instabilities and of the rate at which the beam might expand under various conditions.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☒ DTIC USERS ☐	Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE NUMBER (Include Area Code)	22c. OFFICE SYMBOL
Capt. Henry L. Pugh, Jr.	202-767-4907	NP

84 04 03 159

SUMMARY

This final report covers the work carried out under the Air Force Office of Scientific Research Grant, #AFOSR 83-0203 made to Princeton University during the period June 15, 1983 to January 15, 1984. This grant formed the conclusion of research first carried out under research grant #AFOSR-81-0106. During this concluding period we completed the investigation of the amount of neutralization of the energetic ion beam and carried out preliminary investigations of possible instabilities and of the rate at which the beam might expand under various conditions.

In this report our final conclusions are summarized in section I. The relative papers presented and submitted for publication are listed in section II. Personal engaged are listed in section III.
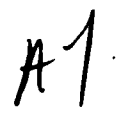
I. ACTIVITIES AND ACCOMPLISHMENTS

The main effort of our group under these grants is to investigate the possibility of propagating a low density high energy ion beam a large distance across the ionsphere. The model used to investigate this question is described in the last final report and paper 3. Based on this model we conclude that, instabilities aside, it should be possible to accelerate an ion beam of sufficient current that its magnetic field will hold it together against various repulsive forces that it will not expand laterally and will indeed propagate a long distance.

Considerable effort was devoted to checking the accuracy of the numerical solution of the model. In particular an analytic solution, valid for the limiting case of a beam density small compared to the ionospheric density, was shown to give results consistent with those of the numerical solution, valid for ion beams of arbitrary density relative to the ionospheric density. This gave us confidence in the numerical solution.

A illustrative case of a beam that would propagate without radial expansion is one with parameters 10^5 beam ions/cm^3, energy 100Mev/nucleon and radius 10^2 cm^2. We assume the ionspheric density is 10^5 electron/cm^3. The angular divergence of the beam is .5 milliradians. The rise time of the beam from zero to full current need be longer than 0.5 μ sec corresponding to a beam length greater than 0.6km. For such a beam sufficient charge neutralization occurs that the self magnetic field of the beam can confine it against radial expansion and beam divergence. The beam if H$^+$, would be bent into a circle of radius 100km by the earth's field. If it where Ne$^+$, it would propagate in a radius of 2000km. This example is discussed in reference (3).

The theory was carried out assuming propagation perpendicular to the earths' field. In this case there was no current neutralization of the ions

by the charge neutralizing electrons so that the maximum confining magnetic field was produced. If propagation occurs at another angle, some neutralization will occur, but in most cases it is small enough that the beam is confined.

A preliminary investigation of the Weibel instability connected with electron motions showed that it probably does not occur because of finite geometry. The same holds for two-stream instabilities. It is planned to write these results up in the near future.

Our final conclusion from our research is that if energetic ion beams can be produced in space then they can be propagated a long distance.

II. PUBLICATION AND CONTRIBUTED PAPERS

1. "Propagation of Ion Beams Through a Magnetized Plasma" E. F. Chrien and R. M. Kulsrud (New York APS Meeting, November 1981) Bull Am Phys. Soc. <u>26</u>, 871 (1981).

2. "Charge Neutralization of Ion Beams Propagating Through a Magnetized Plasma" E.F. Chrien, E. J. Valeo, R. M. Kulsrud, and C. R. Oberman.

3. Propagation of Ion beams Through a Tenuous Plasma E. F. Chrien, E. J. Valeo R. M. Kulsrud and C. R. Oberman Princeton Plasma Physics Laboratory Report MATT 2100 and submitted to Physics of Fluids

III. PERSONNEL SUPPORTED

The persons supported by this grant during the period June 15, 1983 to January 15, 1984 were.

L. Chen

R. M. Kulsrud

C. R. Oberman

W. M. Tang

E. J. Valeo

END

FILMED

5-84

DTIC